Il doppio senso della scienza (G. Ghirlanda – Brera 30/11/2016)
giancarlo.ghirlanda@brera.inaf.it

J. Bell Burnell racconta la storia della scoperta delle pulsar (con commento sul Nobel) http://www.bigear.org/vol1no1/burnell.htm

Archivio digitalizzato dei lavori di Einstein:
http://einsteinpapers.press.princeton.edu

"Einstein, Eddington and the Eclipse" (Peter Coles)
http://arxiv.org/pdf/astro-ph/0102462v1.pdf

"Einstein" per i quaderni delle scienze (dicembre 1998) Le Scienze

Le Scienze, Numero Speciale "Einstein" Novembre 2015.

"Einstein, dalla relativita' alle onde gravitazionali", Grandangolo (in edicola con il Corriere) inizio Novembre.

Osservatorio Astronomico di Brera INAF

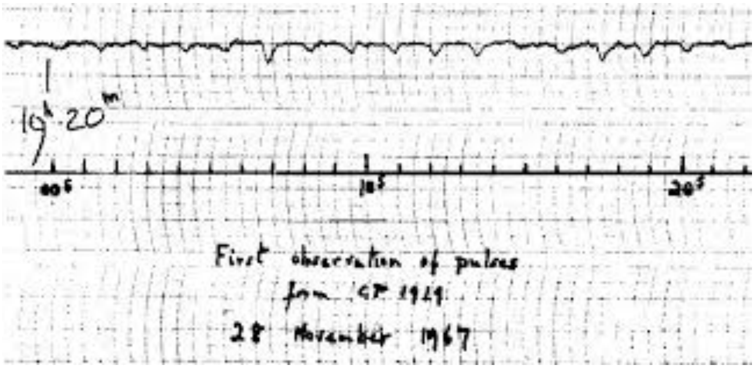
IL DOPPIO SENSO della SCIENZA

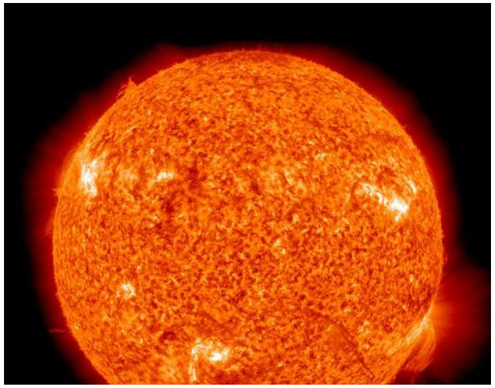
Giancarlo Ghirlanda
giancarlo.ghirlanda@brera.inaf.it

30/11/2016 – Corso Avanzato

Ricerca astronomica/fisica

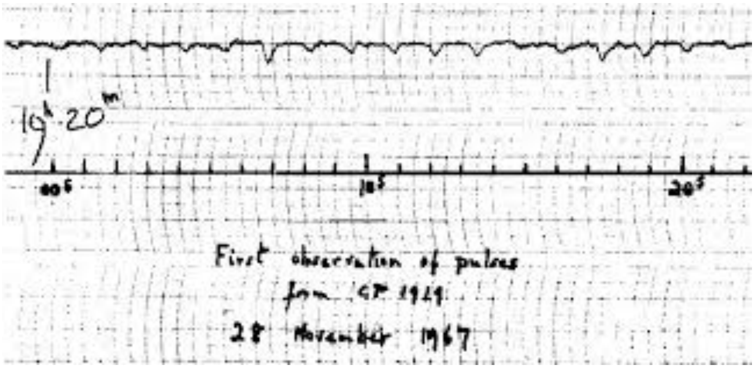
Little Green Men

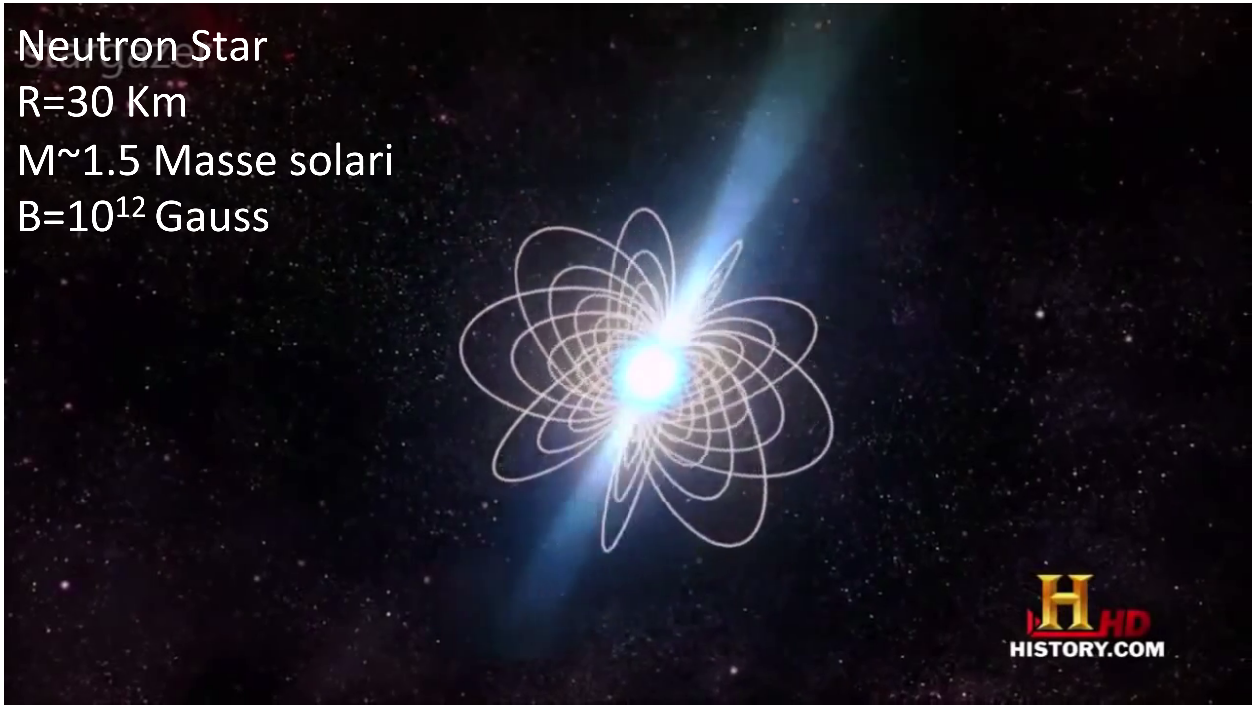




1.4 g cm^{-3}
[130 g cm^{-3}]

Pulsar



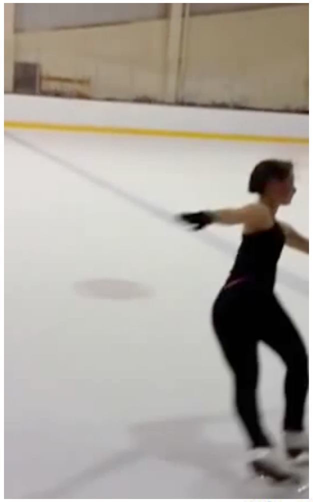


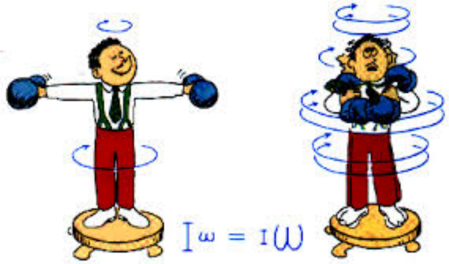
Le pulsazioni osservate … oggetti velocemente rotanti che emettono un fascio di luce (orientato "di sbieco")

PERCHE’ RUOTANO COSI’ VELOCEMENTE?

$$\mathcal{L} = I\,\Omega$$

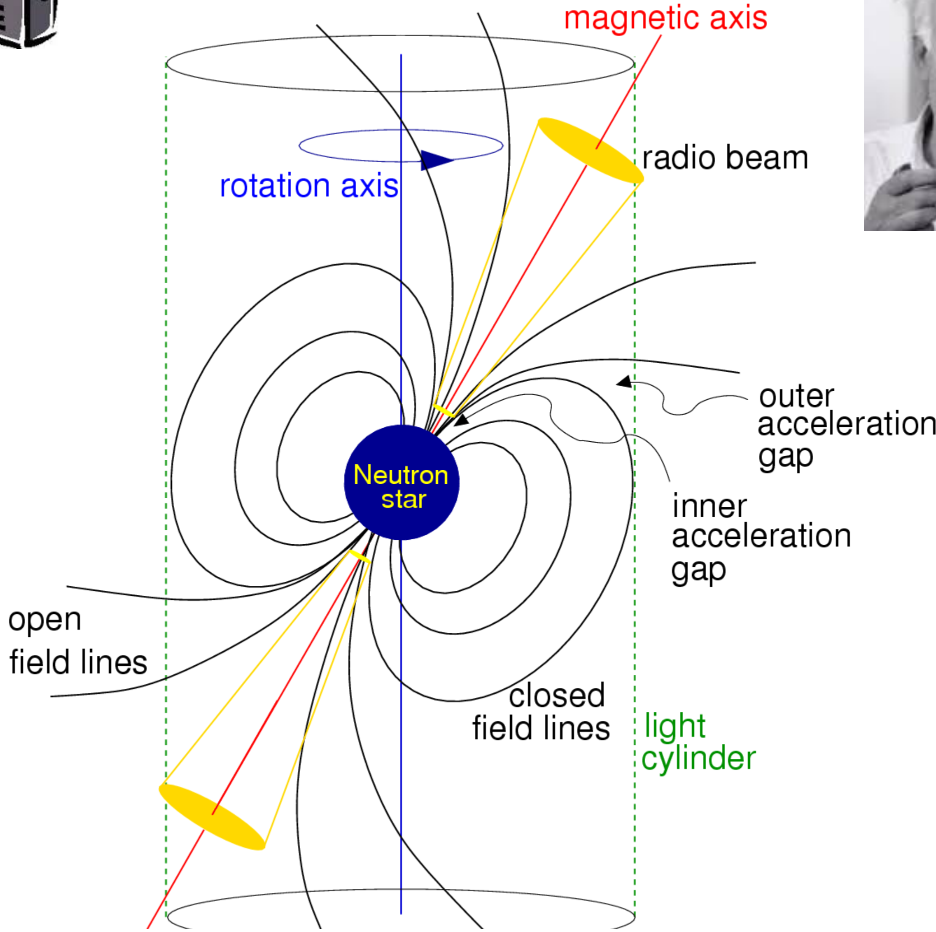
Momento angolare SI CONSERVA



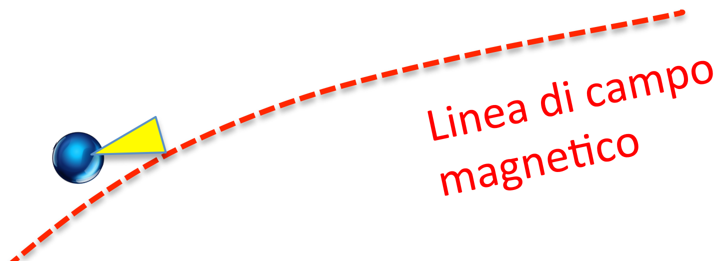


Che cosa produce la luce che vediamo?

CLASSE 1: Rotation Powered Pulsars

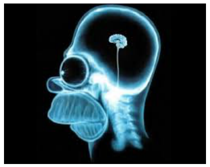


Una carica accelerata produce luce

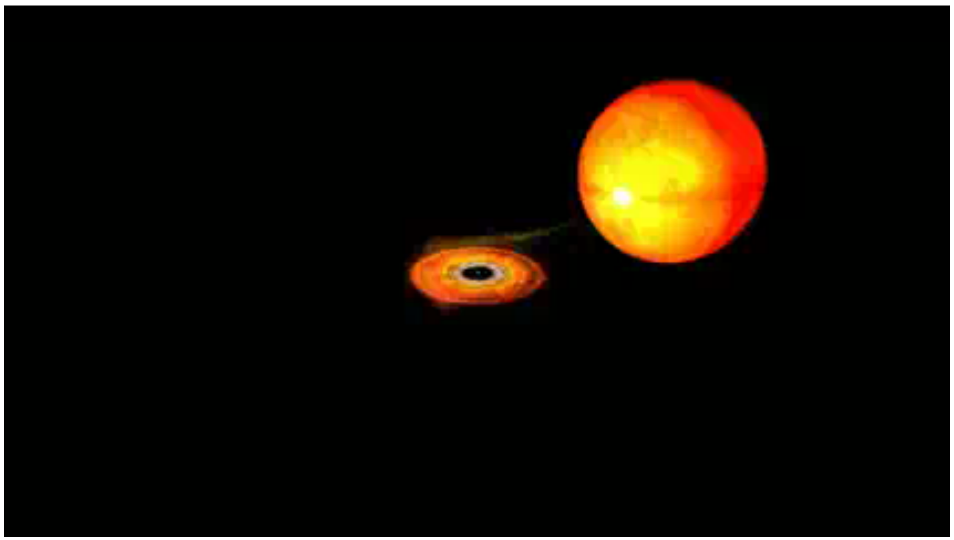


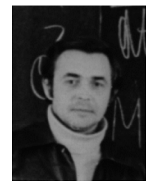
$$L = \frac{2}{3}\frac{m_e r_e}{c} a^2$$

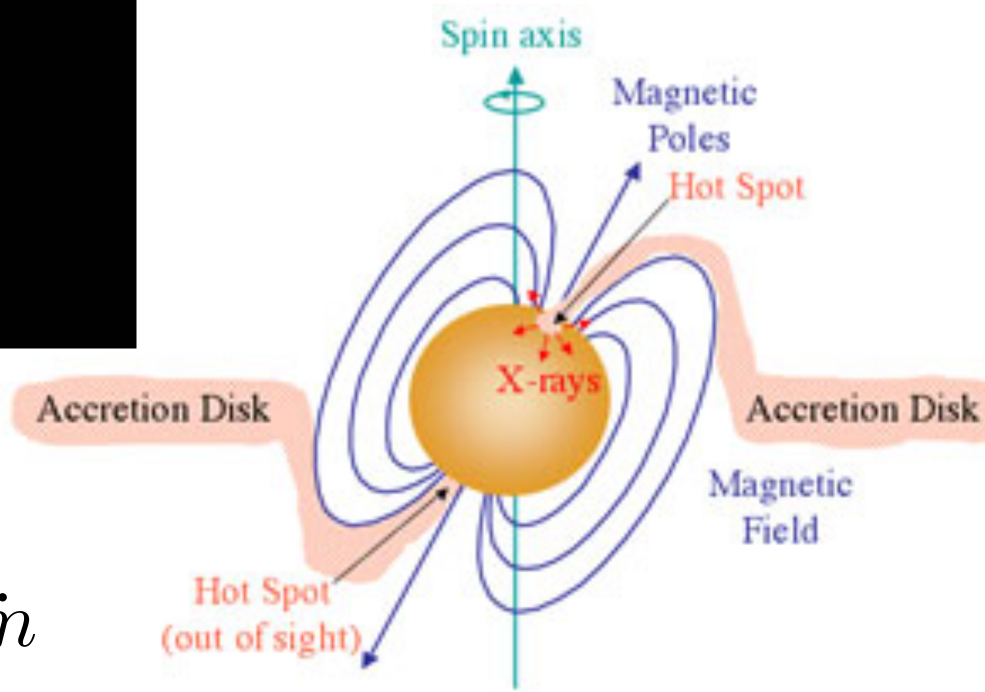
Che cosa produce la luce che vediamo?



CLASSE 2: Accretion Powered Pulsars



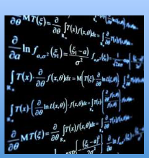


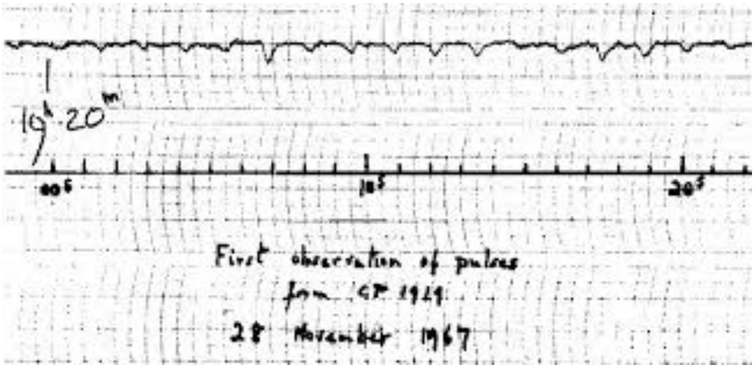


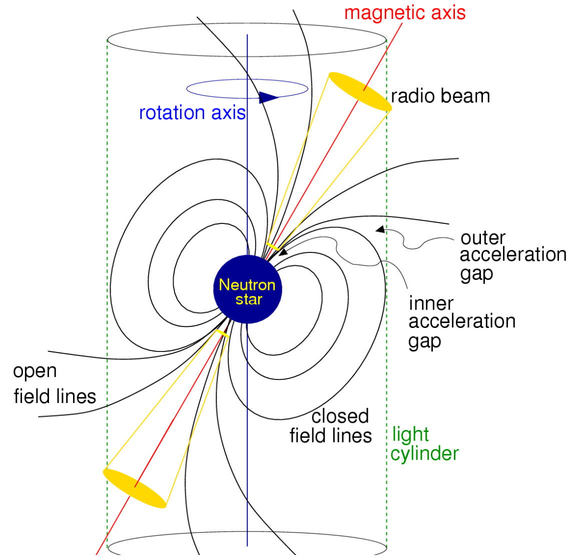
$$U = \frac{G\,M}{R} m$$

$$L = \frac{G\,M}{R} \dot{m}$$

Pulsar… come e' finita?







Observation of a Rapidly Pulsating Radio Source

A. HEWISH, S. J. BELL, J. D. H. PILKINGTON, P. F. SCOTT & R. A. COLLINS

Mullard Radio Astronomy Observatory, Cavendish Laboratory, University of Cambridge

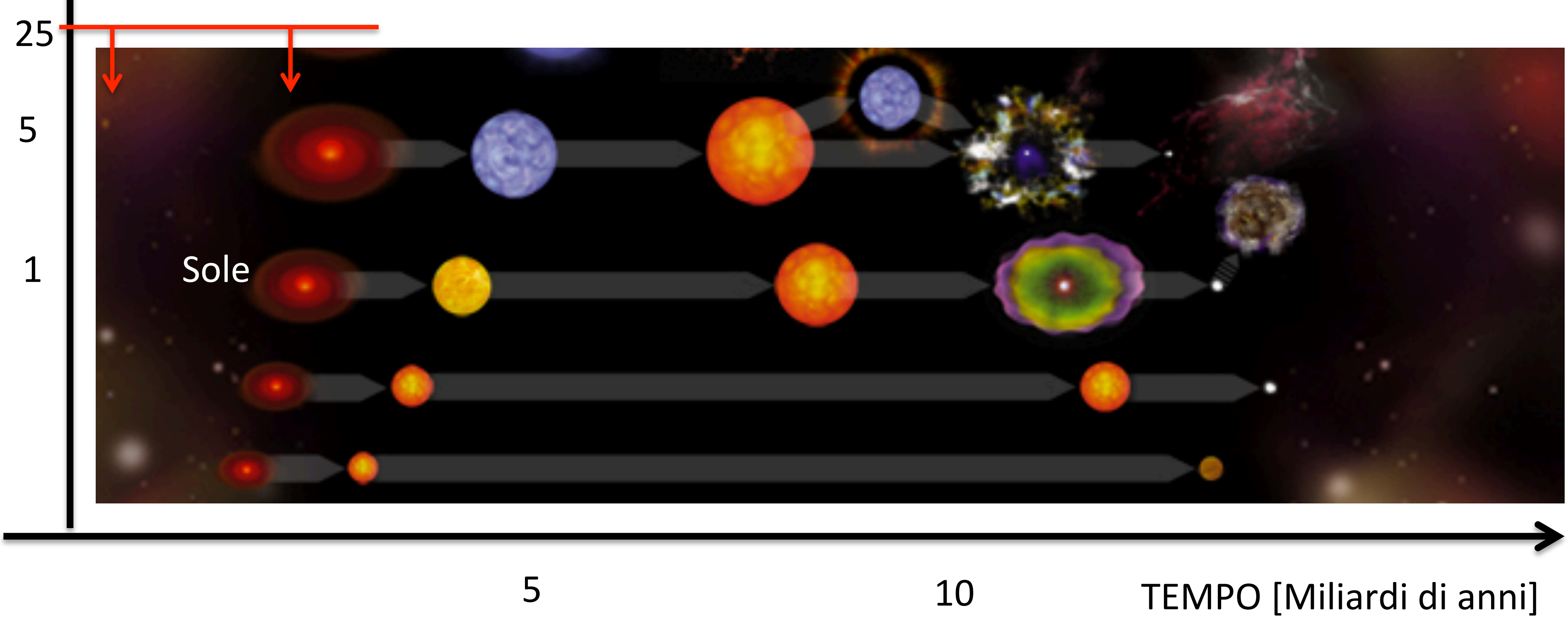
Unusual signals from pulsating radio sources have been recorded at the Mullard Radio Astronomy Observatory. The radiation seems to come from local objects within the galaxy, and may be associated with oscillations of white dwarf or neutron stars.

"… Finally, I am not myself upset about it - after all, I am in good company, am I not!"

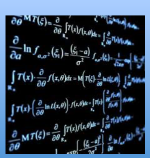
Quando finisce il carburante

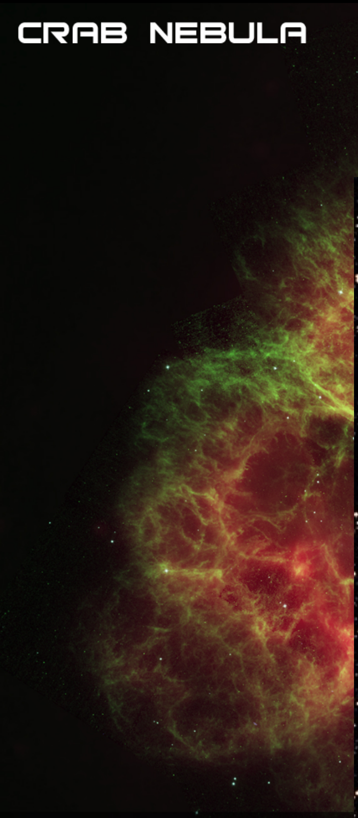
Baade W, Zwicky F (1934) On super-novae. *Proc Natl Acad Sci USA* **20**(5):254–259

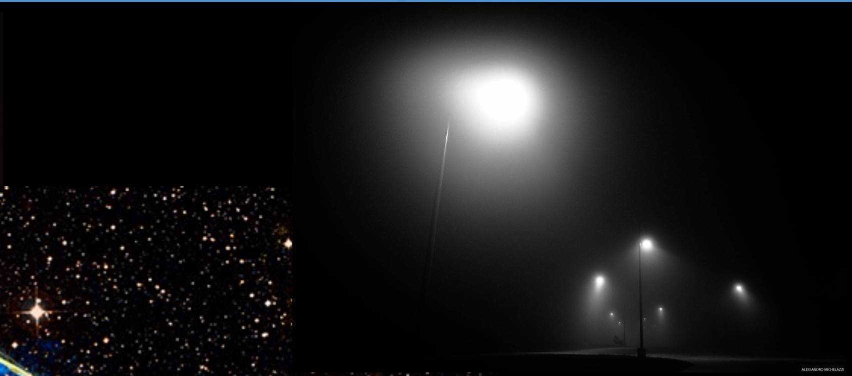
"With all reserve we advance the view that a super-nova represents the transition of an ordinary star into a neutron star, consisting mainly of neutrons. Such a star may possess a very small radius and an extremely high density."

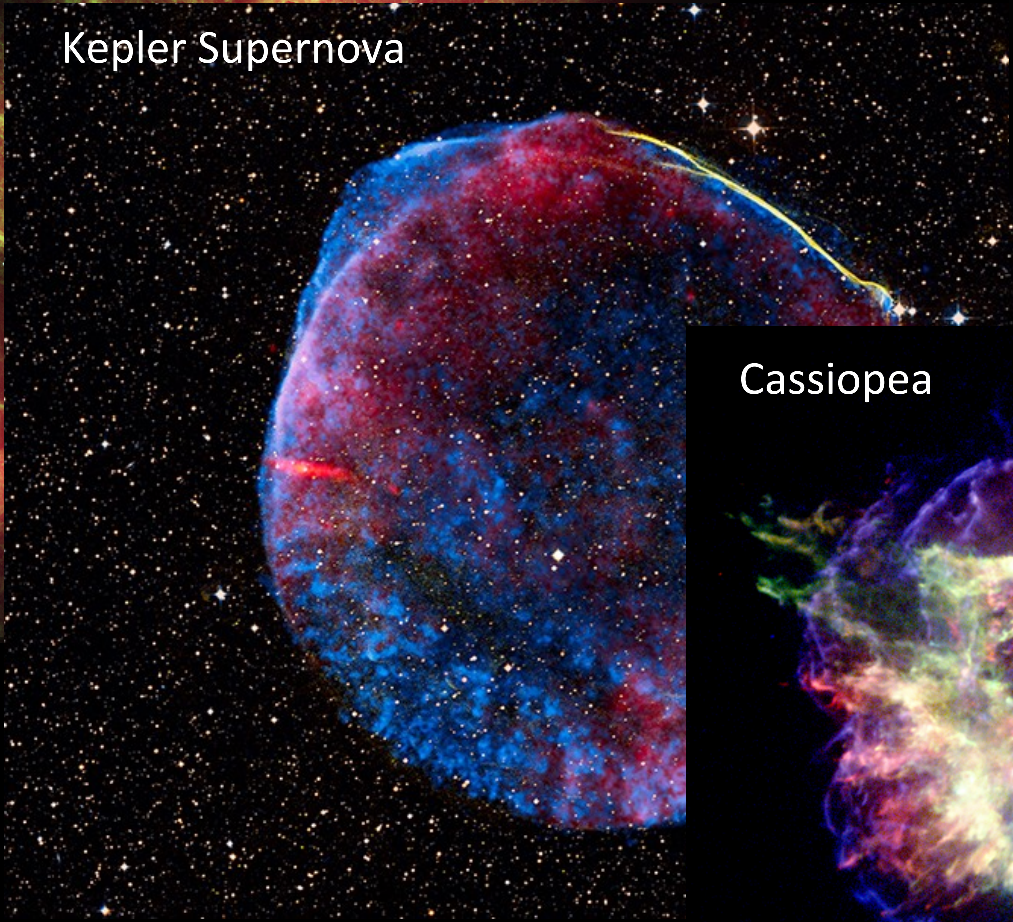


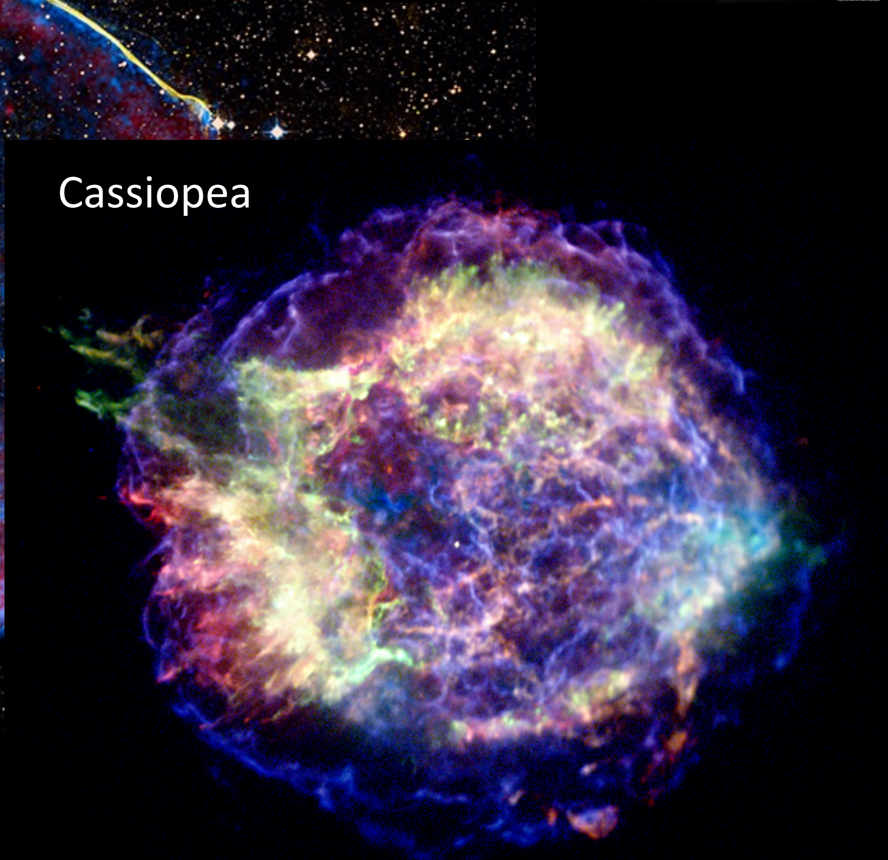
“Polvere” di stelle



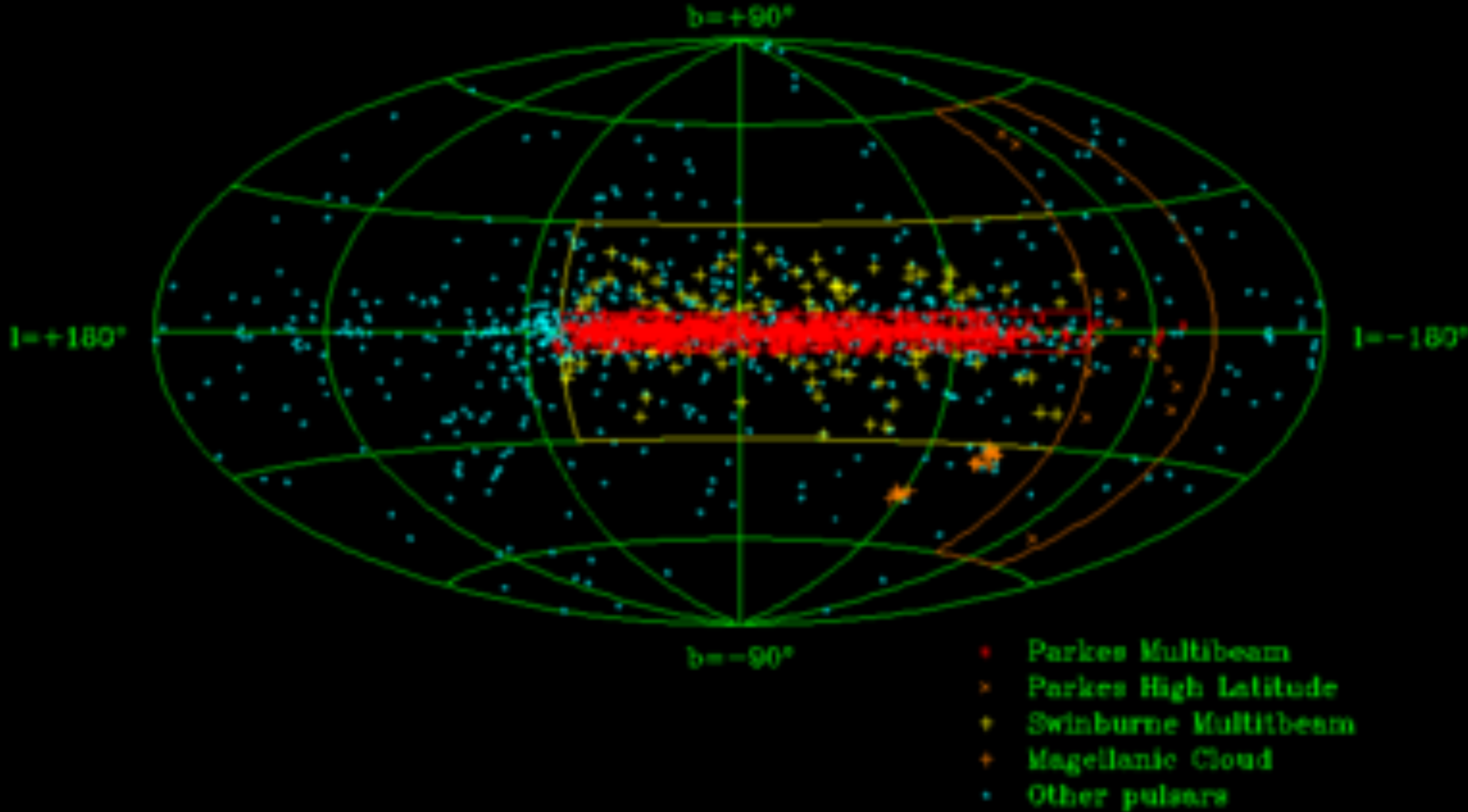








Pulsar (quante e dove)



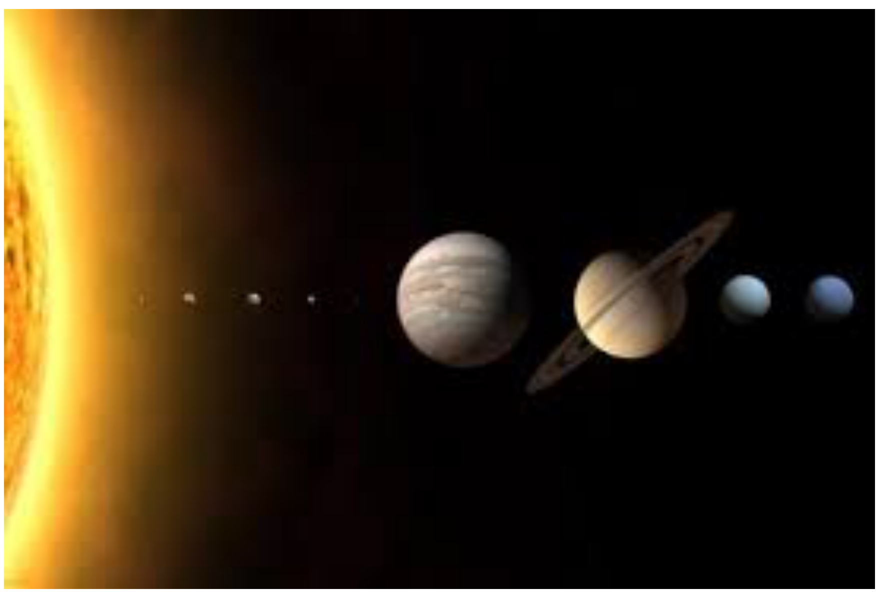
La teoria: Newton

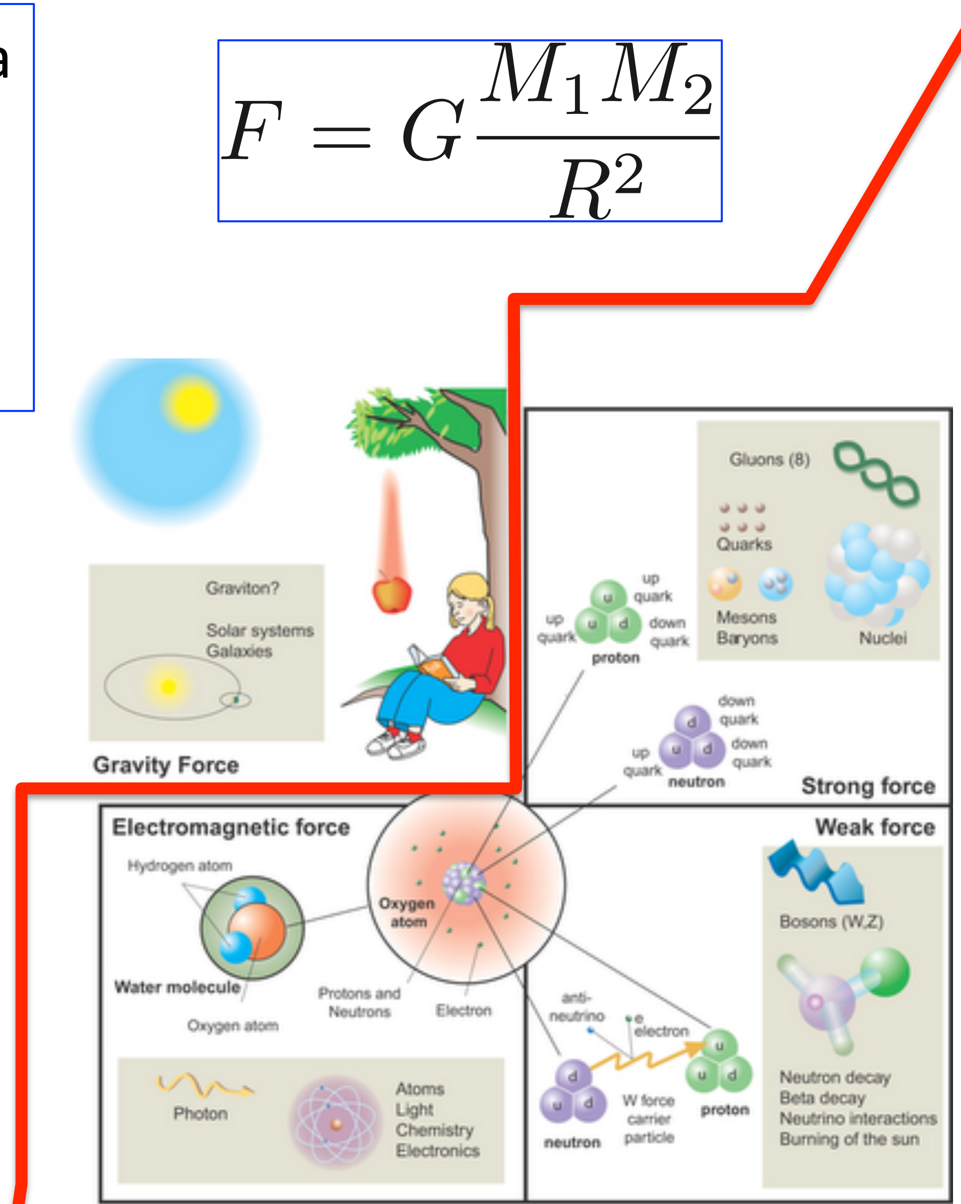
1) Principio di inerzia

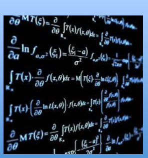
2) $F = ma$

3) Azione e reazione

$$F = G\frac{M_1 M_2}{R^2}$$



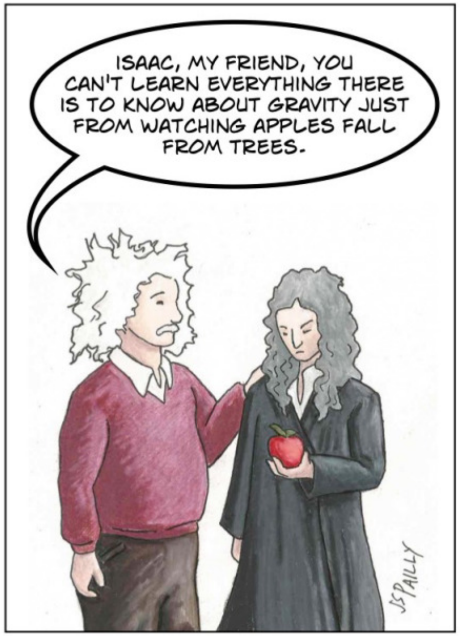




Marzo – Giugno 1905 ANNUS MIRABILIS

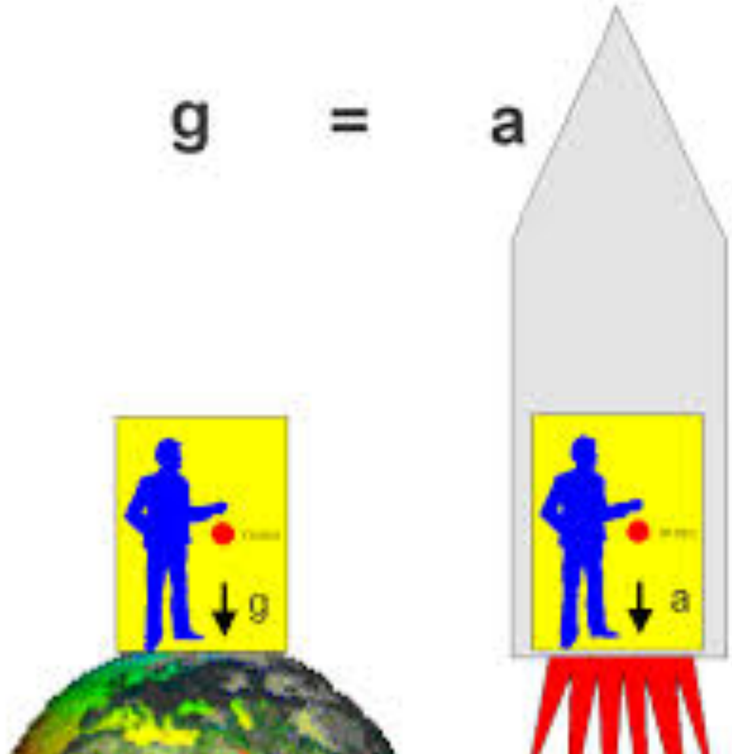
1. "Il primo ha per oggetto la radiazione e le proprieta' energetiche della luce ed e' decisamente rivoluzionario (La luce e' fatta di particelle fotoni ...)
2. Il secondo e' una determinazione delle dimensioni effettive degli atomi
3. Il terzo dimostra che corpi delle dimensioni di 1/1000 di mm in sospensione nei liquidi sono soggetti a un moto casuale generato dall'agitazione termica (moto browniano)
4. Il quarto e' soltanto un abbozzo iniziale ed e' un'elettrodinamica dei corpi in movimento che fa un ricorso ad una modificazione della teoria dello spazio tempo (relativita')"

La teoria: verso la relativita' generale



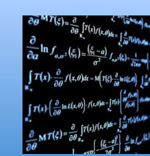
1907... "il pensiero piu' felice della mia vita" = "se una persona cade liberamente non sentirà il proprio peso"

Esperimento Mentale [Gedankenexperiment]



Principio di Equivalenza: gli effetti locali della gravita' (**g**) e dell'accelerazione (**a**) sono equivalenti. Quindi **gravita'** e **accelerazione** sono manifestazione dello stesso fenomeno

La teoria: massa = curvatura spaziotempo

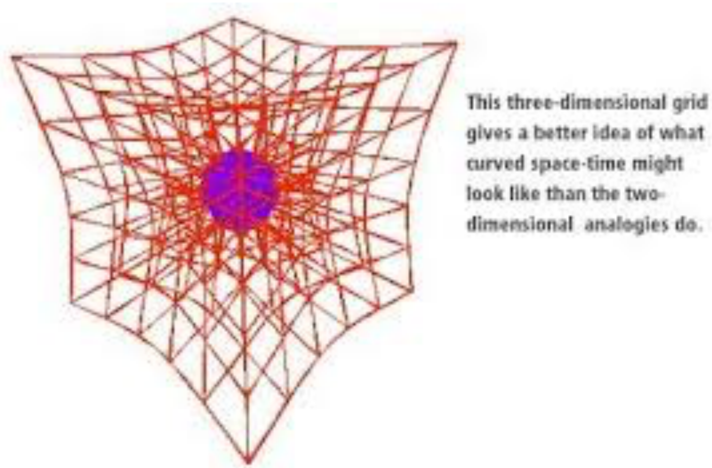


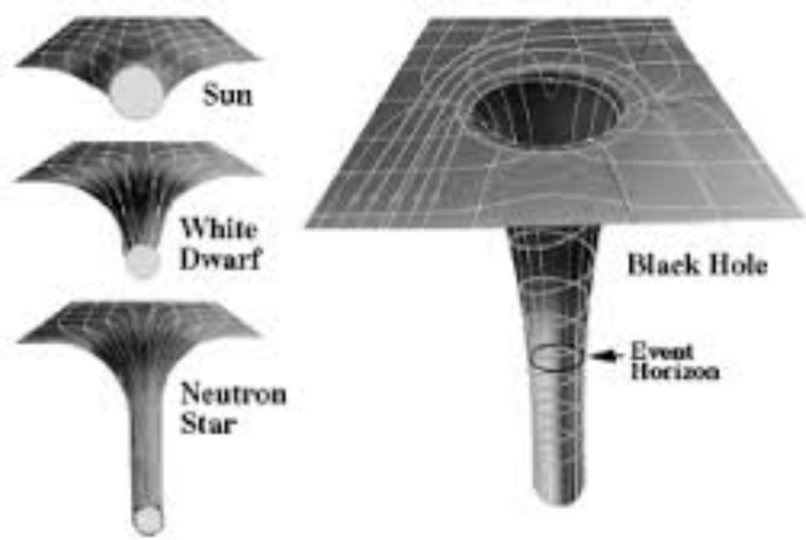
1907 … 1915 verso la relativita' generale

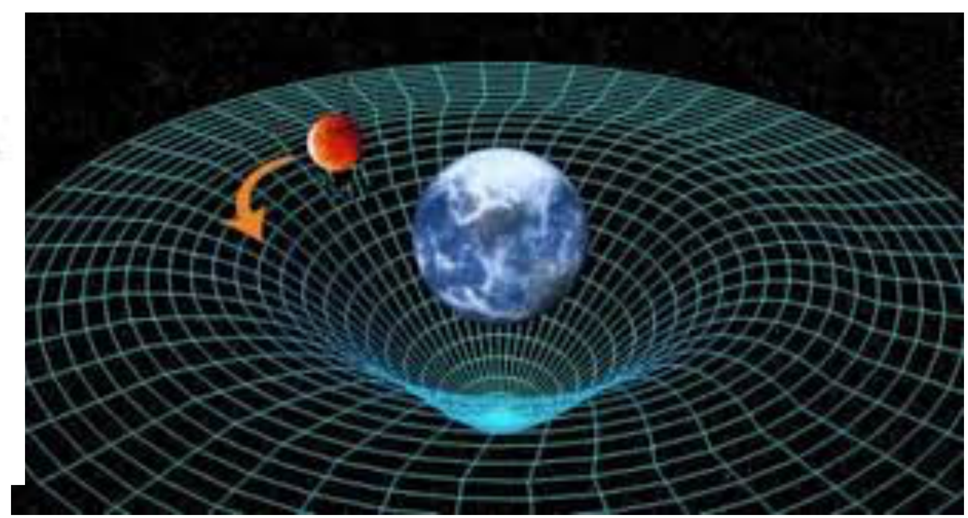
Massa

Curvatura dello spazio tempo

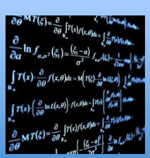
Movimento dei corpi



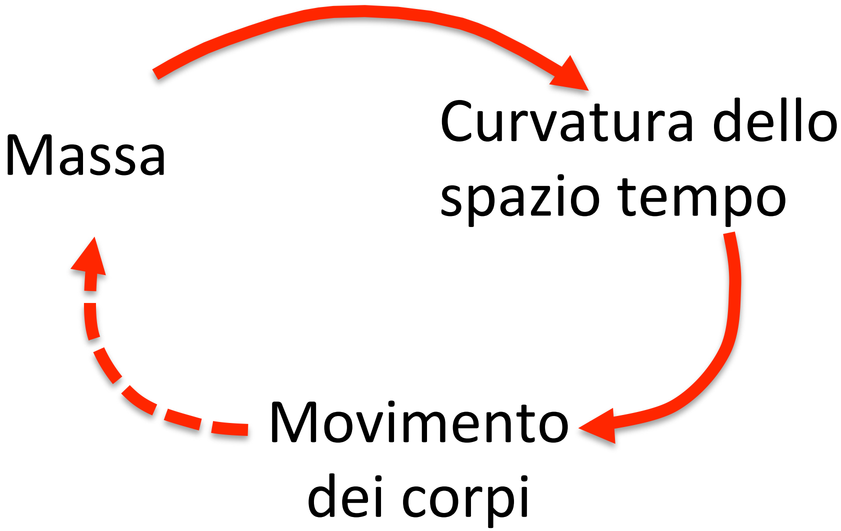




La teoria: equazione di campo di Einstein



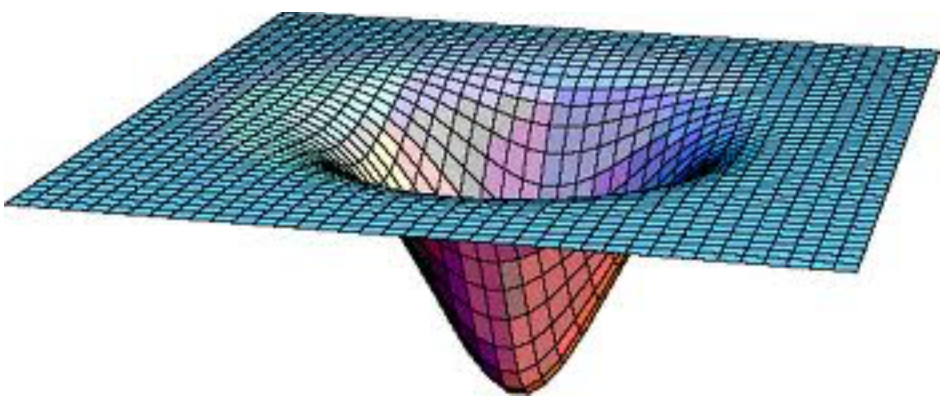
1907 … 1915 verso la relativita' generale

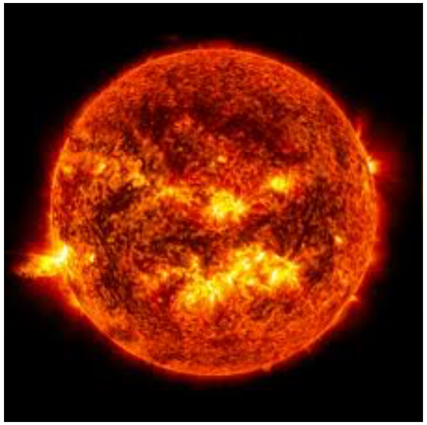


25 Novembre 1915
(4° lezione Accademia
Prussiana delle Scienze)

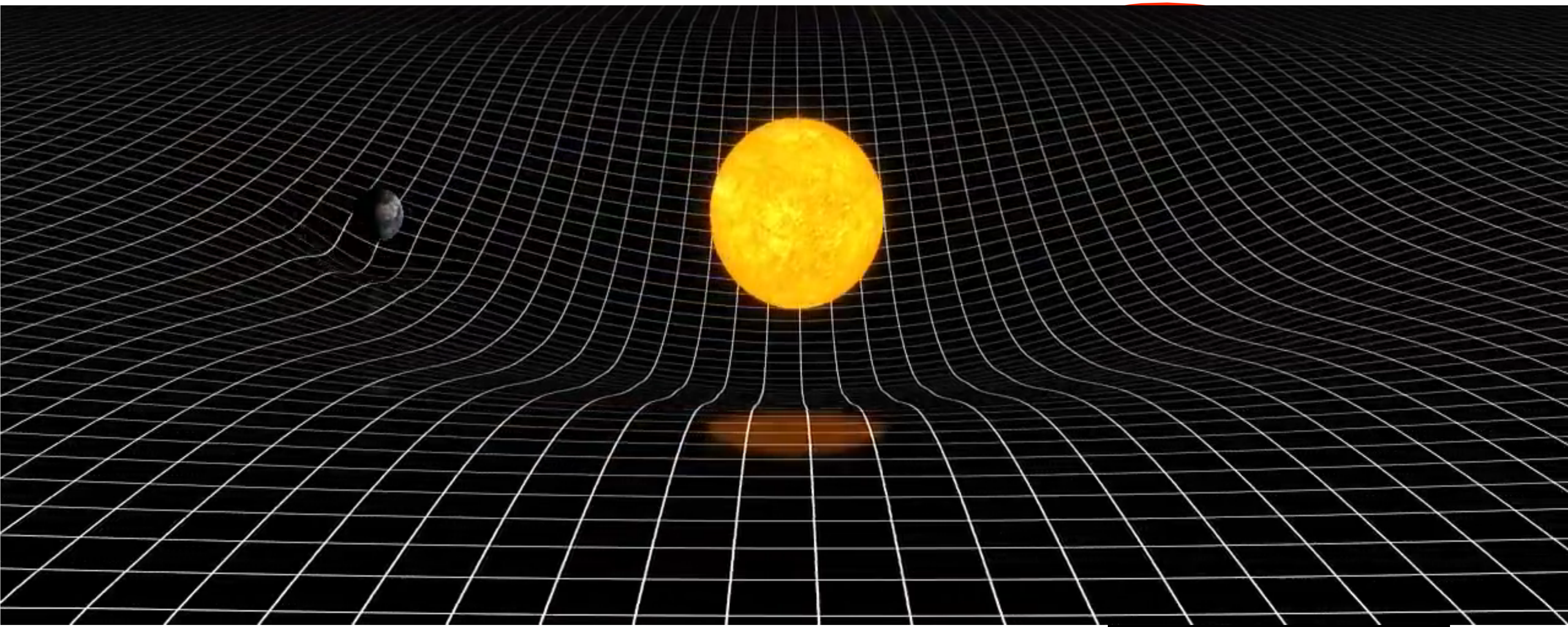
"Le equazioni di campo della gravitazione"

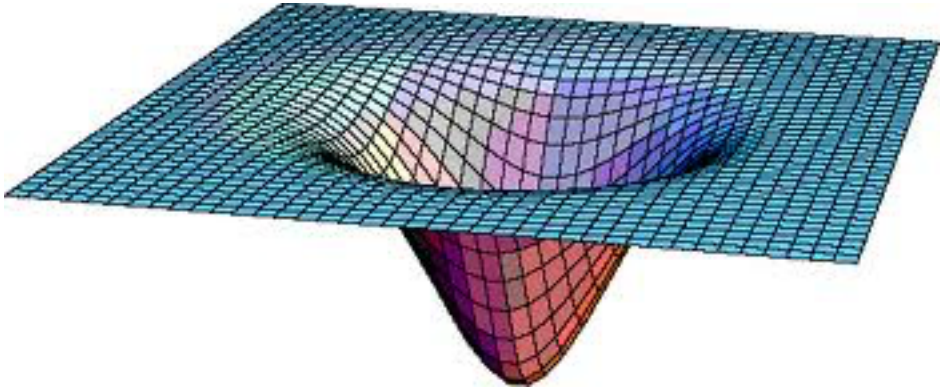
$$R_{\mu\nu} - \frac{1}{2} R \, g_{\mu\nu} = \frac{8\pi G}{c^2} T_{\mu\nu}$$

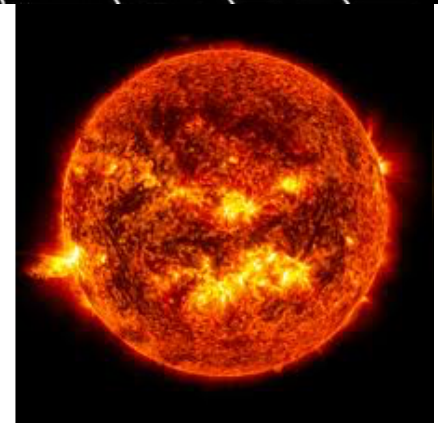




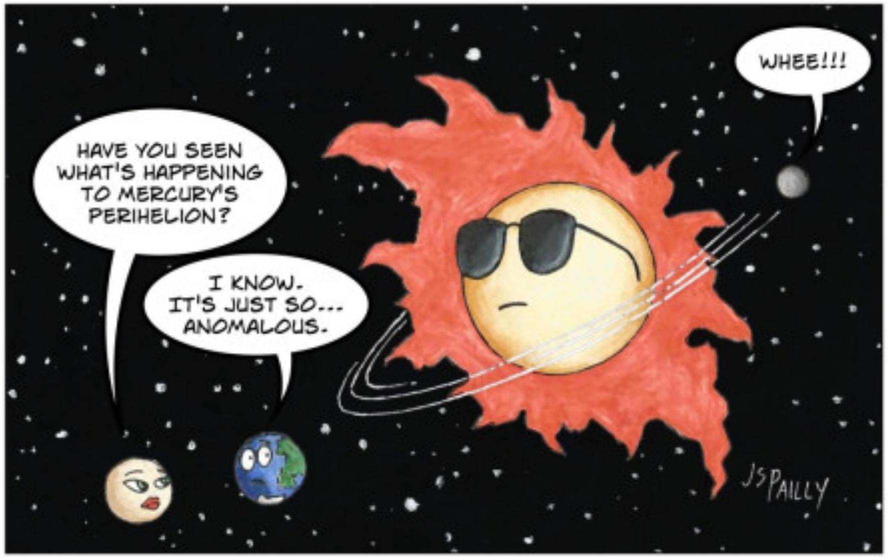
La teoria: GR

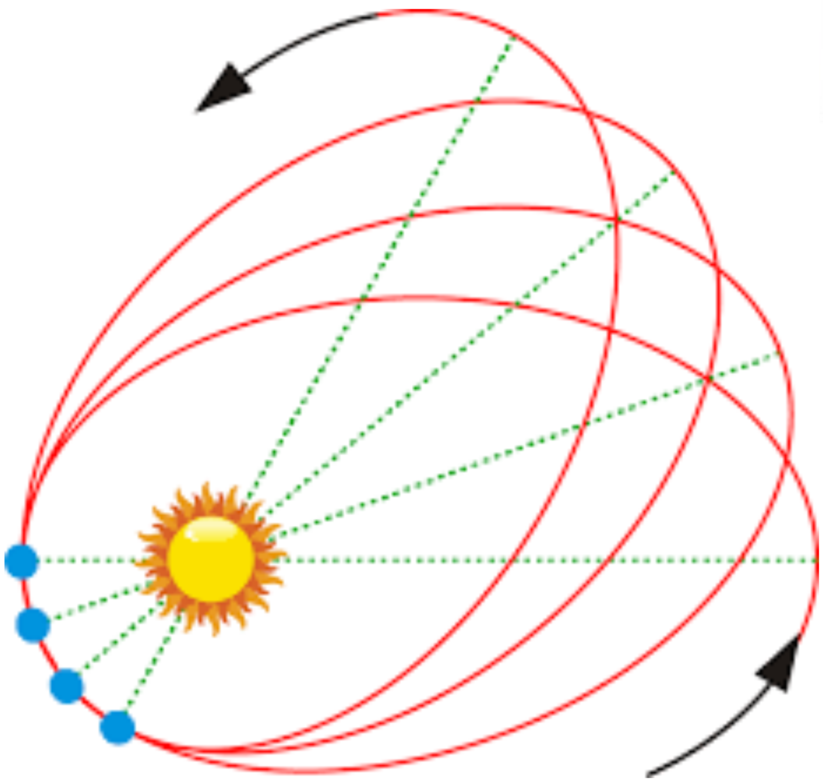


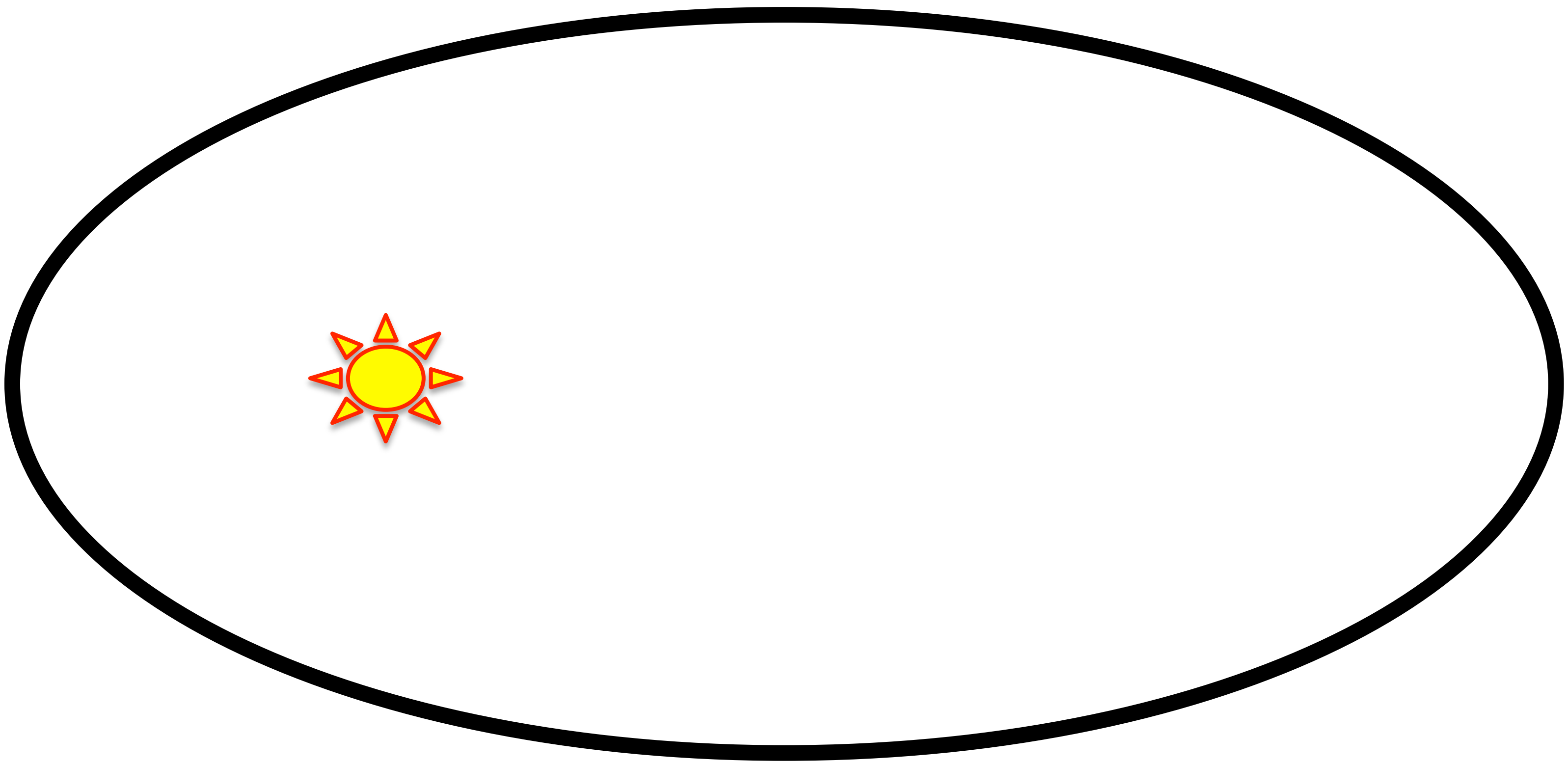




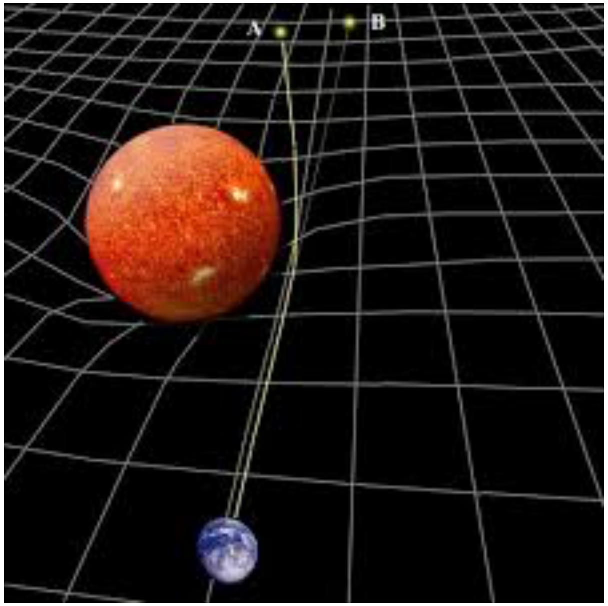
Le prove classiche (1)



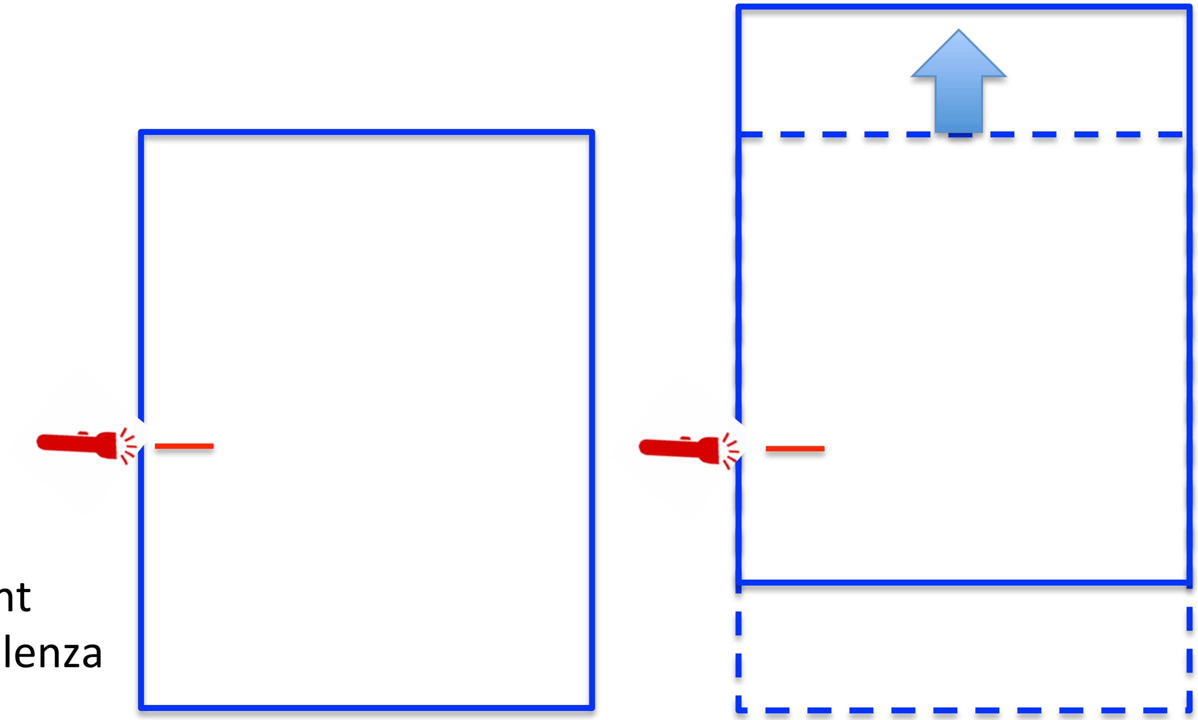




Le prove classiche (2)



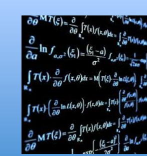
La curvatura della luce

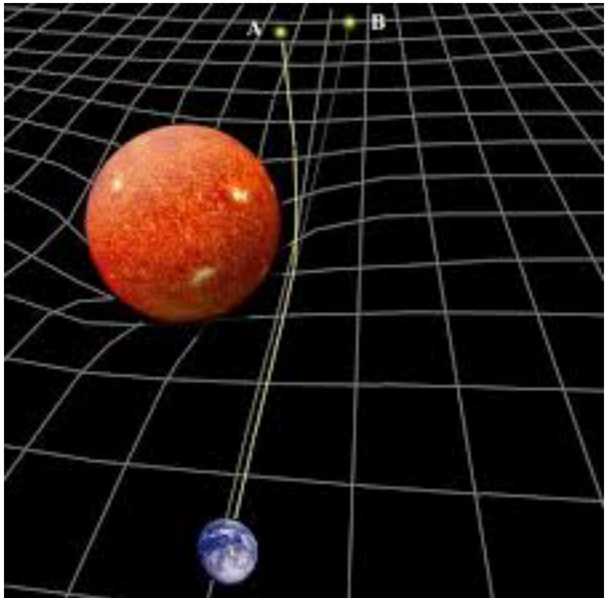


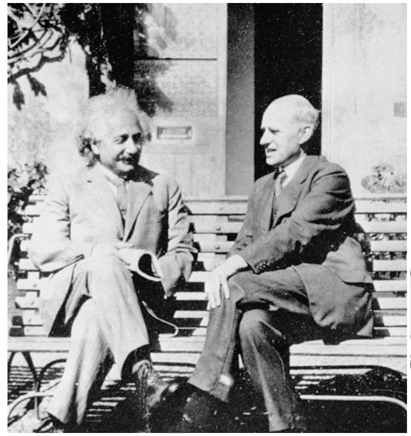
Gedankenexperiment
+ principio di equivalenza

"Do not Bodies act upon Light at a distance and by their action bend its Rays; and is not this action … strongest at the least distance?"
[Opticks, I. Newton]

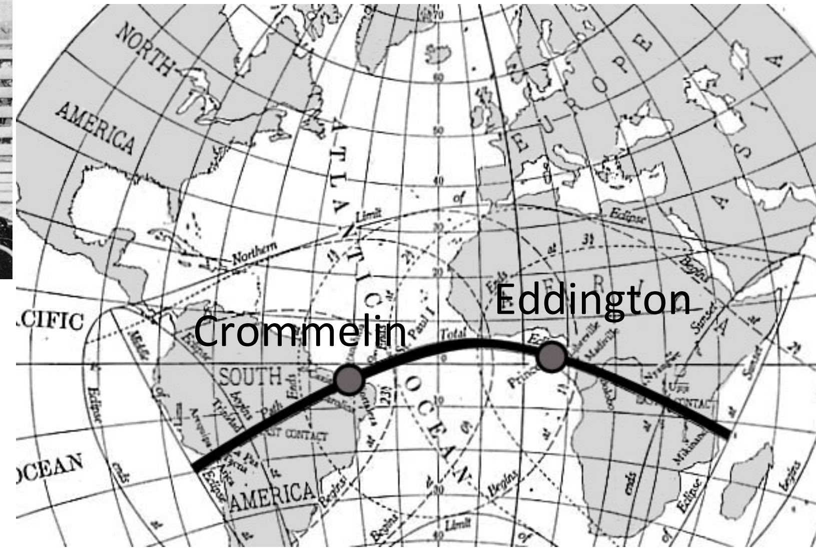
Le prove classiche (2)







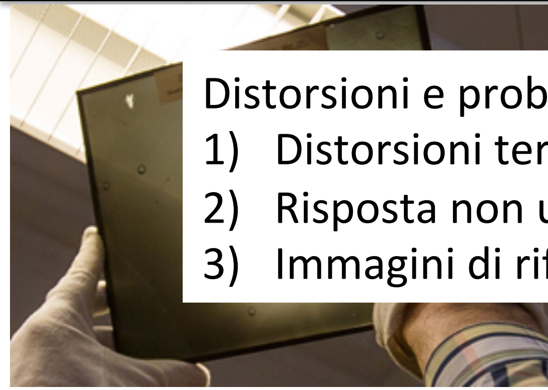
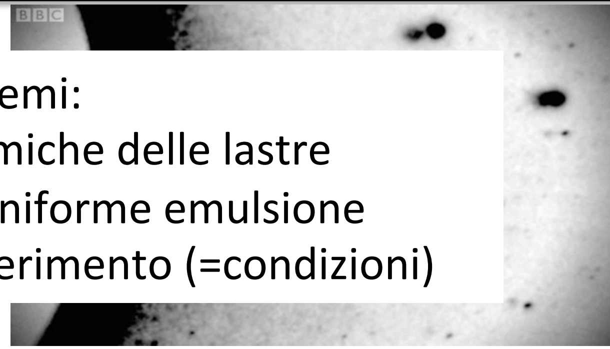
29 Maggio 1919
Eclissi di sole … con dietro le Hyadi



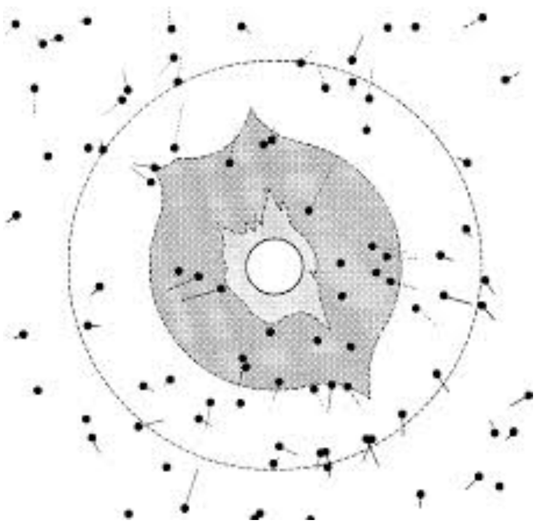
£100 attrezzatura £1000 spedizione

Crommelin: “Eclipse splendid”
Eddington: “Through Cloud. Hopefully”

Le prove classiche (2)

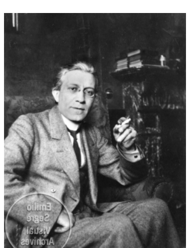



Distorsioni e problemi:
1) Distorsioni termiche delle lastre
2) Risposta non uniforme emulsione
3) Immagini di riferimento (=condizioni)

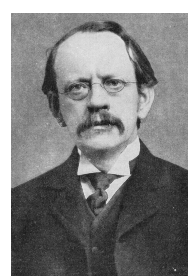


7 stars → 1.98+-0.16''

5 stars → 1.61+-0.40''



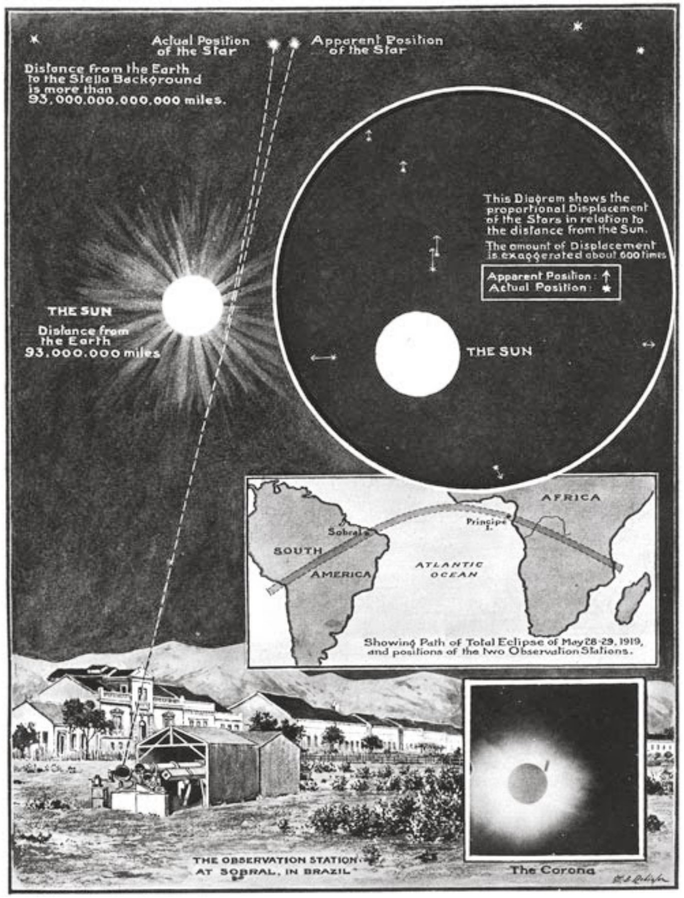
"We owe it to that great man (Newton) to proceed very carefully in modifying or retouchin his Law of Gravitation" (L. Silbersten)



"This is the most important result obtained in connection with the theory of gravitation since Newtons's days" (J. J. Thomson)

Le prove classiche (2)

"… ottime notizie oggi. H. A. Lorentz mi ha telegrafato informandomi che la spedizione Inglese ha misurato la deflessione della luce delle stelle da parte del Sole."



Illustrated London News (1919)

LIGHTS ALL ASKEW IN THE HEAVENS

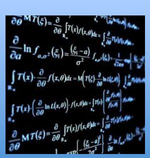
Men of Science More or Less Agog Over Results of Eclipse Observations.

EINSTEIN THEORY TRIUMPHS

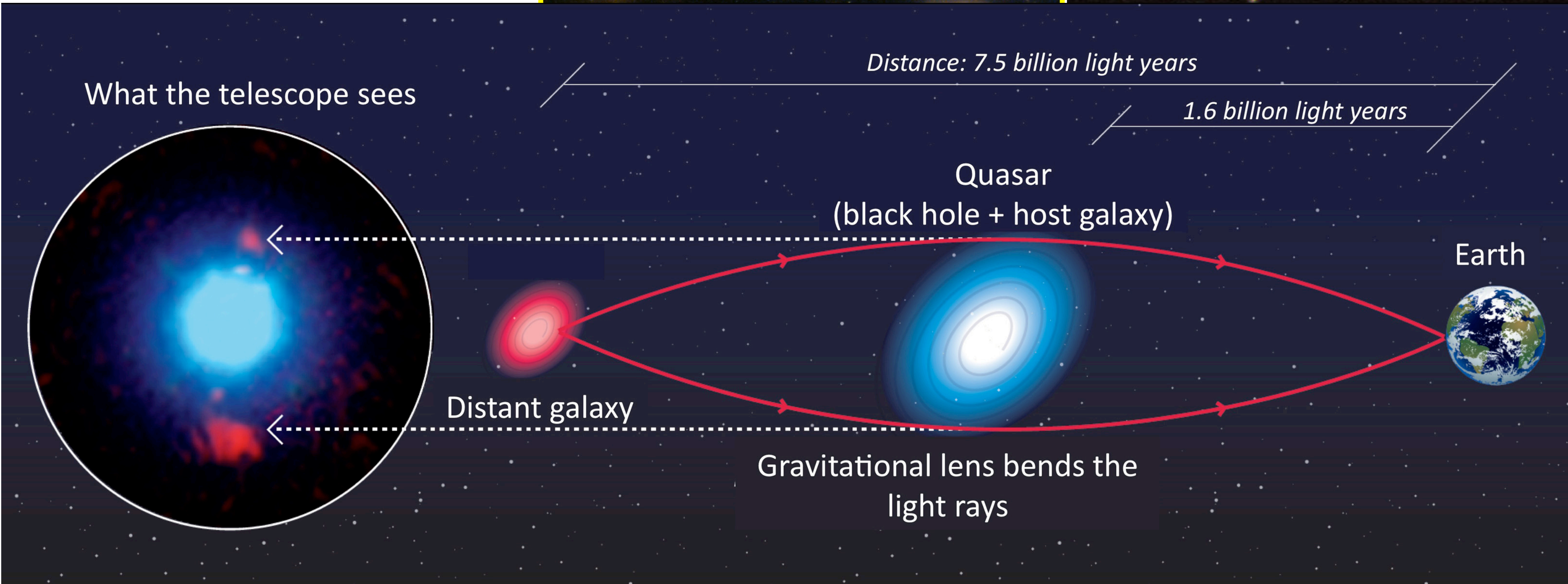
Stars Not Where They Seemed or Were Calculated to be, but Nobody Need Worry.

New York Times (10/11/1919)

La deflessione della luce oggi

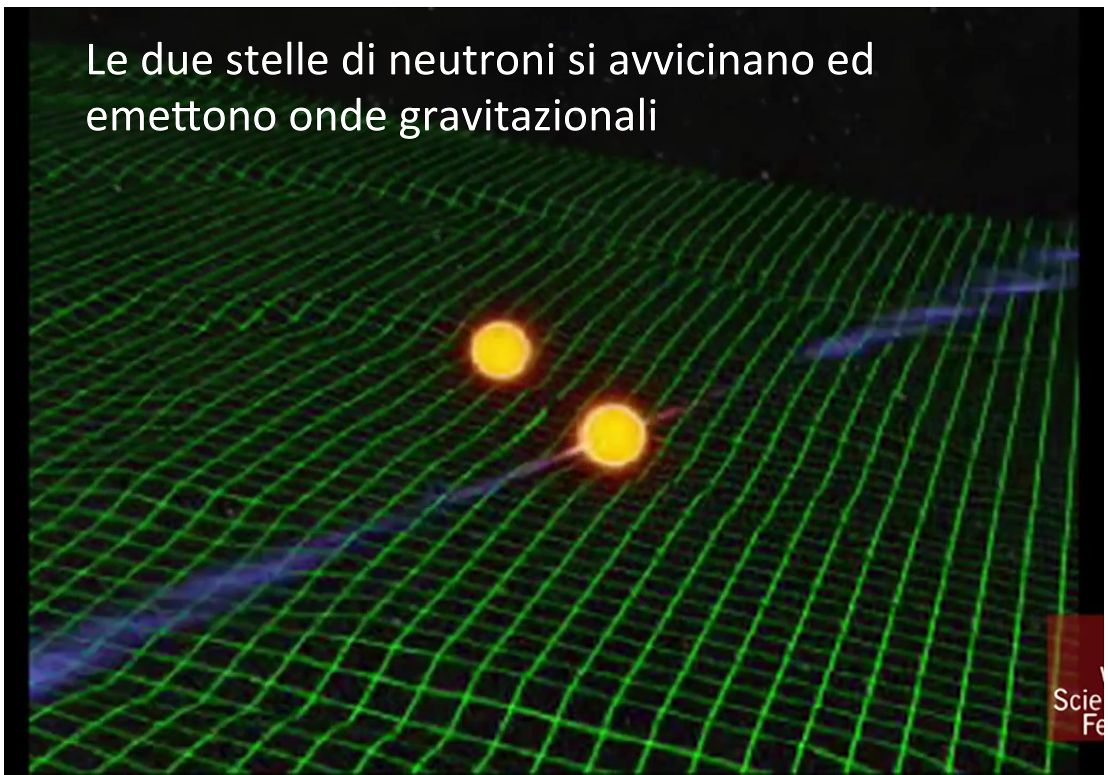


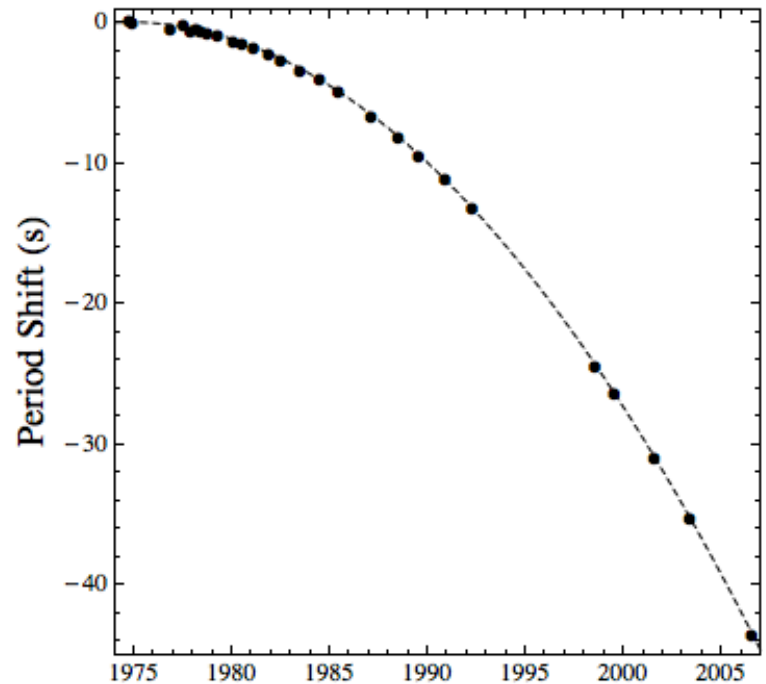
Il telescopio gravitazionale



Le prove moderne: test in campo forte

Hulse & Taylor (NP 1993)





Le misure (pallini) sono perfettamente sulla linea che e' quando previsto dalla teoria della relativita' generale.